Provenance Studies of Clastic Sediments and Their Role in a Hydrodynamic Interpretation of the Genesis Flood

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Abstract

Studies tracing sedimentary particles to their source, referred to by geologists as provenance studies, can play an important role in the hydrodynamic approach to interpreting the rock record. This methodology is superior to the entrenched uniformitarian time-stratigraphic method, which filters interpretation through its geologic column because it 1) resolves presuppositional contradictions between the column and biblical history and 2) provides a sounder empirical foundation for interpretation. Ultimately, the hydrodynamic method could yield 3-D models of the flow regime of the Flood, calibrated to abundant forensic sedimentologic data. Though such models are not presently realistic, the empirical work necessary to support them can be done by the collection of local flow regime information from crustal sediments. Any future model will require calibration to flow information, which must be derived from sedimentological data—such as provenance studies. Examples of such studies suggest interesting lines of inquiry into non-uniformitarian alternatives and demonstrate additional shortcomings of the time-stratigraphic approach.

Introduction

The birth of modern stratigraphy began in the 1600s with the work of Nicolas Steno, who based interpretation on chronological relationships between vertically adjacent sedimentary layers. This was a rational approach for the time—layers are easily observed in the field and the scientific and technological tools for more sophisticated analysis did not exist. Unfortunately, the time-stratigraphic paradigm diverged from, and outlasted, Steno's empirical emphasis (Berthault, 2004; Julien et al., 1993; 1994; Reed et al., 2006).

This unfortunate situation can be laid at the feet of early nineteenth-century uniformitarianism and its emphasis on defining prehistory by geologic time periods. The mania to pigeonhole rocks into prehistoric time periods blinded many geologists to all but bedding boundaries and the newly minted divisions of the geologic timescale. Belatedly, we are now realizing that Lyell and his peers erred in two fundamental ways. First, their strict uniformitarianism has not been able to explain the rock record, hence the recent advent of neocatastrophism. Second, they subordinated empirical science in their quest to displace biblical history with secular prehistory. When push came to shove, they

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maintained the preeminence of their philosophical uniformitarianism over empiricism. As a result, geologic history has become increasingly divorced from the empirical method. This has resulted in an internal tension within geology between empirical observation and the time-stratigraphic framework of natural history (Ager, 1993a; 1993b).

The time-stratigraphic approach is being challenged on a more fundamental level by some diluvialists—by presuppositional critiques (Reed, 2001; 2008a; 2008b) and experimental data (Berthault, 2002; Julien et al., 1993; 1994). The way is being paved for an alternative—and more empirical—method of investigating the rock record. This new method is that of paleohydraulic reconstruction from sedimentologic data.

Some diluvial studies have been conducted along these lines (Table I), applying experimentally derived thresholds for erosion and deposition to field-measurable parameters such as grain size, bedding, and sedimentary structures. Tools developed by uniformitarian sedimentology, such as paleocurrent analysis and provenance studies, fit well within this method, but the uniformitarians stop short of using the full potential of these empirical studies because they limit themselves by the walls of their time-stratigraphic shibboleth—the geological timescale.

Table I. Paleohydraulic Approach

Author	Summary of Work
Allen, 1996	Hawkesbury Sandstone of southeastern Australia - depositional constraints. Much background info.
Austin, 2003	Catastrophic deposition of Redwall Limestone member demanded by nautiloid graveyard
Berthault, 2004	Tonto Group (Tapeats SS, Bright Angel Sh, Mauv LS) of Grand Canyon interpreted as single deposit
Froede, 2004	Traced siliciclastics from the Appalachians to the Navajo Sandstone.
Froede, 2006	Traced pebbles and sands down the length of the Florida peninsula.
Howe and Froede, 1999	Traced distant origin of cobbles and boulders in the Marathon Basin, Texas.
Lalomov, 2001; 2003	Tavrick and Demerdji formations of Crimea show rapid deposition; transport from Ukraine
Lalomov et al., 2006	Cambro-Ordovician clastics near St. Petersburg were deposited rapidly as one sequence; erosion surfaces show variations in flow, not time.
Lalomov, 2007	Grain size analysis shows that Crimean Jurassic sediments formed catastrophically.
Oard and Klevberg, 1998	Cyprus Hills Gravel shows large, Flood currents carrying boulders, cobbles hundreds of miles.
Oard and Klevberg, 2005	Rim Gravels in Arizona show transport prior to erosion of central AZ south of Mogollon Rim.
Oard, 2008	Nenana Gravels deposited as Alaska Range is uplifted in late Flood receding currents
Sigler and Wingerden, 1998	Catastrophic origin of Kingston Peak Formation, Mojave Desert, California
Snelling, 2008	Addressed possibility of Appalachian origin for western sandstones.

However, diluvialists understand that if the rock record is largely the result of the Genesis Flood, it is a reasonable strategy of forensic natural history to attempt to derive the three-dimensional hydraulic flow regime of the Flood over its 371-day duration. This is a daunting task, if for no other reason than its scale. Yet it is a worthy goal, because ironically it could provide the most *scientific* interpretation of the rock record.

Approximation of the Flood's paleohydrology can be derived by two complementary methods: (1) forensic examination of preserved flow indicators (such as grain size or cross-bedding) in the rock record, and (2) numerical modeling of three-dimensional hydraulic flow nets using varied sets of proposed parameters. In the best of all possible worlds, modelers and sedimentologists would work together to integrate modeling with forensic sedimentology. At present, there have only been two published numerical modeling solutions (Barnette and Baumgardner, 1994; Prabhu et al., 2008), and neither appears to have made any attempt to incorporate sedimentological data.

However, vast amounts of paleocurrent data exist in the geological literature, and the theoretical foundations for interpreting sedimentary observations are available, though sadly underutilized (cf. Julien, 1995; Pye, 1994). To be of use to diluvialists, these field data must be excised of all aspects of their uniformitarian interpretation. That bias exists to multiple levels, since presuppositions often drive conclusions that then become the foundation for additional theorizing. Some—like conclusions based on the timescale—are easily detected, but others are not. However, the goal of deriving floodwater flow regimes deserves the best efforts by diluvialists.

One area of forensic sedimentology that may prove helpful for providing coarse flow directions, as well as transport distance and current dimension, is that of provenance studies. These provide an origin point for transport, which in turn suggests flow paths, current dimension, and flow velocity, providing a good approximation of transport that can be refined by more detailed studies and models. If it is possible to track a sedimentary clast from its origin, through its transport, and to its depositional and postdepositional fate, then a viable hydrodynamic reconstruction should also be possible.

But before we address these studies, we must first examine the present state of modeling the hydrodynamic flow regime of the Flood.

Limits of Modeling

Numerical modeling is a relatively recent tool that is beginning to come into its own, thanks to exponential leaps in computing power. Predictive models based on sound hydraulic engineering principles have been developed for other areas, especially in the atmospheric and groundwater sciences. At present, there is still a significant tradeoff between scale and detail. Clearly the best models are those that are able to incorporate the most parameters and be well calibrated to field observations.

Diluvial flow models are rare; at present only two numerical models of Flood flow patterns exist—those of Barnette and Baumgardner (1994) and of Prabhu et al. (2008). Although both models address global conditions, both are very coarse 2-D models, quite limited in their assumptions and parameterization. Neither model was calibrated to quantitative field data. Despite these shortcomings, both represent a start in a promising area of research. Both provide initial qualitative and conceptual flow patterns that might be helpful on a very gross scale. Apparent local discrepancies—both empirical and conceptual—are part and parcel of the limits of these models.

Thus, diluvialists should be cautious in applying their results to specific field studies. At best, both assume initial conditions more conducive to the middle of the Flood because of their use of the Pangean "supercontinent." Both are forced to ignore numerous hydraulic factors undoubtedly determinative of the actual flow regime, such as vertical flow gradients; the effects of turbulent flow; pressure, temperature, and density gradients; and chemical properties of water that might affect flow properties. Likewise, geologic factors that would influence flow, such as uplift and downwarping, were not incorporated. Neither could present an explanation of Flood flow conditions at its onset, which would naturally have exerted a profound influence on subsequent flow conditions. Furthermore, the Bible, in Psalm 104:5–9, suggests that the late Flood drainage off the continents resulted from large vertical changes in the relative elevations of both continents and oceans. These changes would profoundly affect a global flow regime; likely decreasing the velocity of the currents where they flowed off the continents into the deepening ocean basins. This would affect flow inland, as would changing base levels and any local tectonic uplift or downwarping.

We must be careful when calibrating numerical models to the rock record because the relative timing of distinct Flood stages cannot easily be located in the rock record, especially when using the questionable chronostratigraphy of the geologic column. It is imperative to understand that the hydrodynamic approach is not intended to supplement the time-stratigraphic approach—it is meant to displace it.

Given these limitations, it is clear that numerical computer models will be most effective when they incorporate the hard realities of the rock record through forensic sedimentology. This is fortunate in one sense: although the models are difficult to construct and run and require rare skills and resources, the work needed to supply data for their calibration is not. Advanced forensic sedimentology can be performed by a broader group of diluvialists. In many cases, it merely involves literature research, extracting the raw data collected for years by uniformitarian researchers. Thus it appears that the present emphasis should be on finding and publishing the flow properties from the rock record. This approach has been successfully applied by diluvialists (Table I). Lalomov et al (2006), who used their own field measurements, demonstrated that even the duration of sedimentation (using minimum experimental thresholds) can be estimated from this type of paleohydraulic analysis—an important component of any model.

Another reason to merge forensic sedimentology with the models is to calibrate modeled flow regimes that may be contrary to field data. For example, Barnette and Baumgardner (1994) showed the rapid establishment of large-scale hydrodynamic gyres on flooded continents. In North America, these gyres were shown to create a counterclockwise flow, increasing in velocity in the northern latitudes. Creationists might be tempted to use that study to support flow directions during the Flood (e.g., Oard, 2008b). That would be premature, given the limited parameters included in that study, and the near certainty of local variations over both time and space in the hydraulic regime, such as topography, tectonics, and vertical flow components of upwelling waters and downwelling density currents.

So at present we are left with several needs: 1) collecting and cataloging field data indicating past flow regimes, 2) building more sophisticated models, and 3) integrating the results. It may be necessary to restrict the scale of initial models to more successfully integrate field data, scaling up as these models prove their ability to explain and predict sedimentological information. Models also should consider the various stages of the Flood and their effects on flow regimes. One way to do so would be to apply paleocurrent indicators, which have the advantage of being plentiful in the literature. Another method, and perhaps one that will be more congenial to continent-scale models, is the determination of sedimentary provenance—the origin of particles in sedimentary formations. For example, these studies suggest that physical forces other than the Coriolis effect were important factors in erosion and deposition during the Flood. Sediment distribution patterns also might demonstrate whether or not the counterclockwise, regional-scale gyres of Barnette and Baumgardner's (1994) model really existed. Future models can then attempt to include the field-derived flow regimes at various locations, providing they can match the Flood stage during which these flows occurred. Obviously, this would be most accurately done for the times near the end of the Flood.

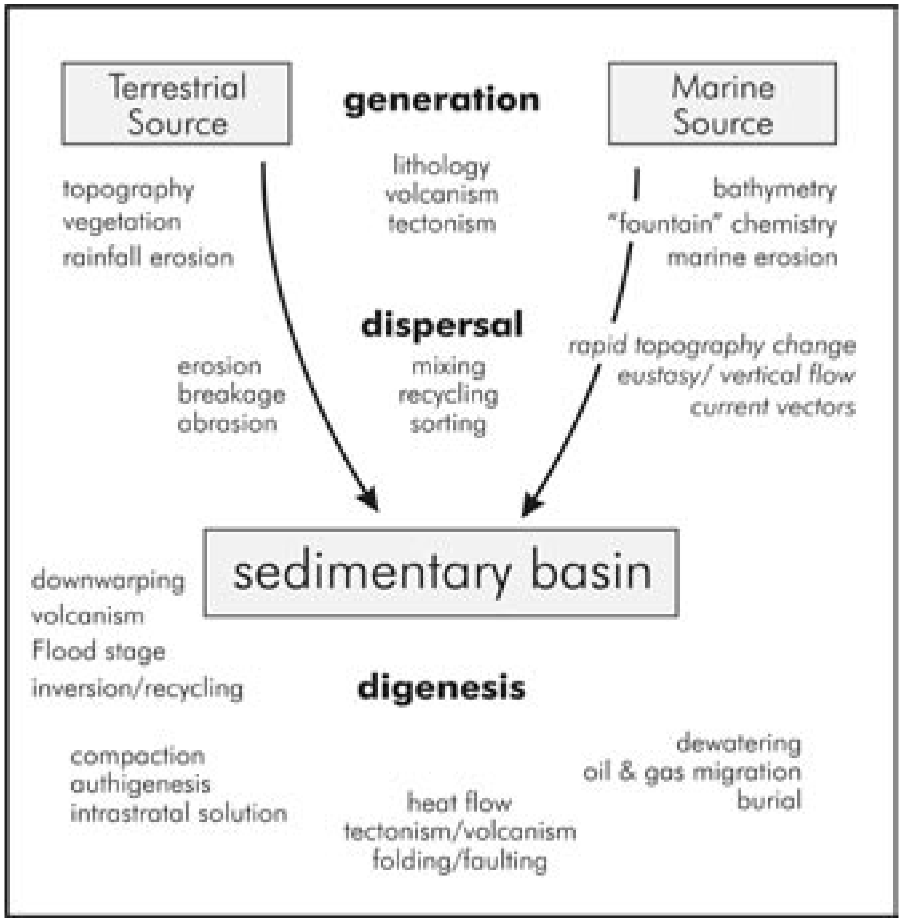

Figure 1. The study of sedimentary provenance attempts to track the changes that occur in sedimentary grains from their initial source to their final depositional location, as well as those that occur after deposition. The multitude of physical processes in the Flood that would have affected this cycle shows the challenges to provenance studies. Modified from Weltje and von Eynatten (2004).

Information from Provenance Studies

Sources of the particles that make up sedimentary deposits have been of interest to sedimentologists for decades (cf. Pettijohn, 1975, chapter 13; Pettijohn et al., 1987, chapter 7). These studies are not always easy—the bulk of clastic sediments are quartz, feldspar, and mica; which are seldom sufficiently unique enough to specify a single source location. Other complications include multiple source areas for the same formation and changes in sediment composition that can occur during transport, deposition, and diagenesis (Figure 1).

However, these problems can be circumvented by examining ratios of these minerals, suites of heavy minerals, and unique individual clasts (e.g., Howe and Froede, 1999; Lalomov, 2007; Oard et al., 2007). Furthermore, sedimentologists in recent years have developed sophisticated quantitative methods for measuring provenance.

> The intent of sedimentary provenance studies is to reconstruct and to interpret the history of sediment from the initial erosion of parent rocks to the final burial of their detritus, i.e., to unravel the line of descent or lineage of the sediment under investigation (Weltje and von Eynatten, 2004, p. 2).

These types of studies can be traced back to the nineteenth century, when the first efforts focused on tracing heavy minerals back to their parent rocks, based on the assumption of unique percentages of such minerals in igneous and metamorphic suites. The development of sedimentary petrography and methods such as counting grains in thin sections broadened the ways in which provenance could be investigated. These led to the inclusion of bulk sedimentary

Figure 2. Dark heavy-mineral sands occur in areas along the Gulf-facing beach at Dauphin Island, Alabama. The heavy mineral suite originated in the southern Appalachian Mountains and consists of ilmenite, kyanite, staurolite, leucoxene, tourmaline, zircon, rutile, sillimanite, and hornblende (Simonson, 1983).

composition in provenance determination and the famous mid-twentieth-century sandstone classification schemes. The late twentieth century saw an increasing focus on quantitative approaches to provenance studies through complex equations and the use of computer models of basin evolution. Many of these studies focus on the tectonic influence of developing "petrofacies" in particular areas. More detailed information can be found in *Sedimentary Geology* (Volume 171; 2004), which was dedicated to provenance analysis.

Unfortunately, uniformitarian assumptions permeate this field: a philosophical commitment to prehistory and deep time, purported similarities between modern and ancient environments, the rejection of catastrophism, and the ongoing motion of tectonic plates.

In spite of the development of sophisticated quantitative provenance studies, practical uses of qualitative studies abound. Many of these are useful for those interested in hydrodynamic modeling of the Flood, providing constraints on current direction, distance, and duration. For example, sediments eroded from multiple source areas can vary in their ratios of kyanite, staurolite, and sillimanite, and these different ratios have been used to identify probable sediment source areas across the United States Gulf Coastal Plain (e.g., van Andel, 1960; Mange and Otvos, 2005). Across this same area, heavy minerals (garnet, zircon, ilmenite, pyroxene, amphibole, epidote, tourmaline, magnetite, and rutile) also have proven useful in provenance studies (Carver, 1986; Dickinson, 1985; Dickinson and Suczek, 1979; Oivanki, 1994; Sabeen et al., 2002; Simonson, 1983) (Figure 2). As long as creationists beware of improper assumptions, such as provenance studies using fossil suites based on evolutionary progression or those relying on radiometric age-dating techniques (Oard, in press), many published studies can be useful. We can extract the raw data from uniformitarian studies to provide coarse paloehydrodynamic information in a diluvial setting. Several examples are presented to illustrate how provenance studies can constrain diluvial interpretation (Figure 3).

A. **Navajo Sandstone and Coconino Sandstone—Utah/Arizona.** Recent provenance studies of the Navajo and Coconino sandstones suggest that they were derived from the uplifted Appalachian Mountains (Dickinson and Gehrels, 2009). Since these sandstones are located on the western side of the Rocky Mountains, they constrain the relative timing of uplift for the Appalachian and Rocky Mountains. This also suggests two further points of interest for diluvialists: that during this time, floodwater flowed in an east-to-west direction, and that currents were large enough to transport sediments several thousand km (Froede, 2004; Snelling, 2008). Similar studies of other sedimentary units can help us understand tectonism and hydraulic Flood regimes in other places and for other times during the Flood.

B. **Norphlet Sandstone—Southwestern Alabama.** A provenance study of the mineral suite within this deeply buried sandstone indicates that it was derived from the southern Appalachian Mountains located to the east (Ryan et al., 1987). Thus flow during the transport of the Norphlet sands was to the south, southwest, and was of regional extent.

C. **Upper Pliocene siliciclastics—Florida.** Quartz sands and quartzite pebbles found down the length of the Florida peninsula were derived from the southern Appalachian Mountains (Hine et al., 2009; Warzeski et al., 1996). This indicates that during the late stages of the Flood, north-to-south currents existed in the southeastern USA region, transporting siliciclastic sediments over hundreds

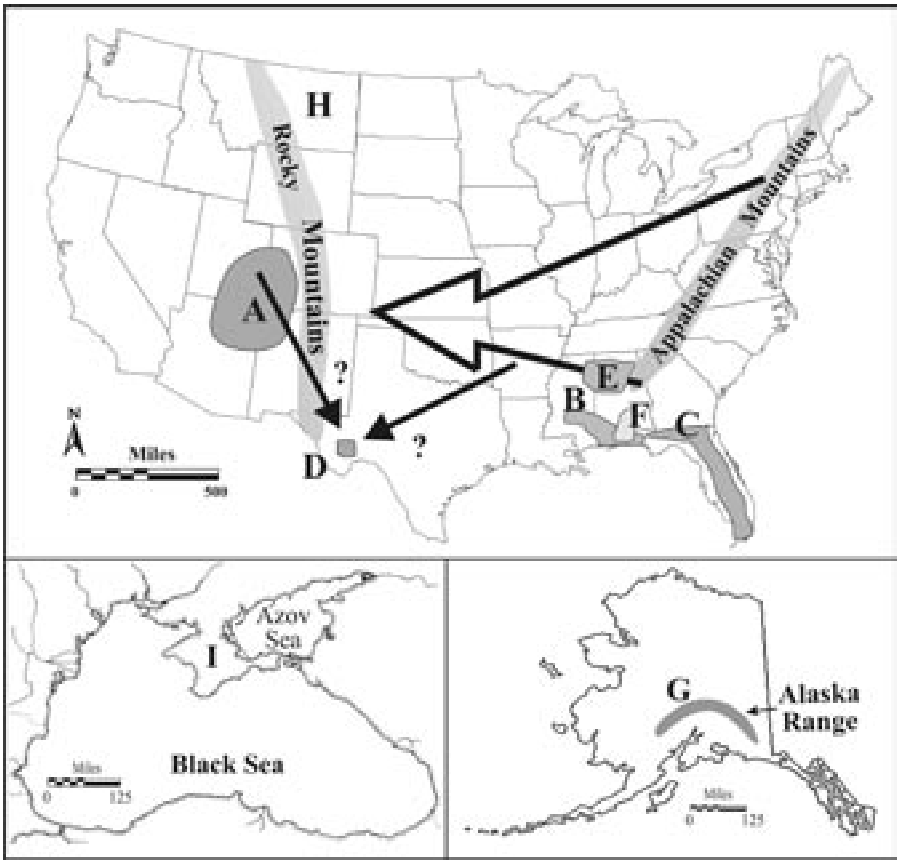

Figure 3. Several provenance studies—most across the continental United States—suggest a complex source-deposit relationship during the Flood. The large letters correspond to the locations discussed in the text: (A) Navajo/Coconino Sandstone, (B) Norphlet Sandstone, (C) Florida Upper Pliocene siliciclastics, (D) Haymond Boulder Beds, (E) Hartselle Sandstone, (F) Alabama Miocene deposits, (G) Nenana Gravels, (H) Cyprus Hills Gravel, and (I) Demerdji Formation. Note that some transport pathways are general and tentative.

Figure 4. These quartz pebbles were eroded from metamorphic vein quartz in the southern Appalachian Mountains and transported south to near Lake Okeechobee, Florida—approximately 550 miles. The anticipated flow velocity and transport distance necessary to erode and move these clasts is consistent with currents expected in the Flood (Froede, 2006).

of miles—all the way to the Florida Keys (Froede, 2006) (Figure 4).

D. **Haymond Formation Boulder Beds—Marathon, Texas.** A study of the provenance of the boulders found within this formation indicates multiple source areas ranging from 125 miles to the southeast, or possibly Utah (northwest), or even farther to source rocks in the southern Appalachians (Howe and Froede, 1999) (Figure 5). This indicates multiple flow paths operating north-to-south, south-to-north, and east-to-west, depending on the ultimate source of the boulders. This shows the potential complexity of the hydrodynamic regime of the Flood. It also constrains the timing of orogenies; if the fossil-bearing boulders were derived from Utah, then they were likely transported to the Marathon Basin *before* the Rocky Mountains were uplifted. None of the boulder transport currents are consistent with the simple gyres predicted by Barnette and Baumgardner (1994), illustrating the complexity over both time and space of flow within the Flood.

E. **Hartselle Sandstone—Northeastern Alabama.** A provenance study was conducted on the Hartselle Sandstone (Mississippian) in the Appalachian fold and thrust belt in northeastern Alabama. The study revealed that the sandstone originated from low-rank metamorphic source rocks derived from the unroofing of the southern Appalachians (Mack et al., 1981). Again, the study indicates southwest flow over hundreds of miles.

F. **Miocene Clastics—Alabama Gulf Coastal Plain.** A provenance study on the sands indicates that they were derived from the southern Appalachian Mountains (Isphording, 1977) and transported southward during the late stages of the Flood.

G. **Nenana Gravels—Alaska.** These sedimentary units north of the Alaska Range were derived from rocks south of range mountains prior to uplift and then from the rising peaks as the Alaska Range was

Figure 5. Large boulders in this exposed road cut in the Marathon Basin, Texas, were derived from multiple source areas—none of which are readily explained by uniformitarian models. The long-distance transport of such large clasts is consistent with the Flood (Howe and Froede, 1999).

Figure 7. Cyprus Hills Gravels, including this cobble, were eroded from outcrops in Idaho and Montana and then transported hundreds of miles by fast-moving Flood currents. The extreme current velocity is also demonstrated by the percussion marks on the resistant quartzite clasts, caused by impacts from other rocks. Photo courtesy of M.J. Oard.

Figure 6. Nenana Gravels derived from Alaska Range. Large, high-velocity currents would have been needed to move these gravels, again consistent with the Flood. From Oard (2008a).

uplifted (Oard, 2008a) (Figure 6).

H. **Cyprus Hills Gravel—Northern Rocky Mountains.** Well-rounded cobbles and boulders were transported hundreds of miles from their sources in Montana and Idaho by powerful and widespread currents (Figure 7). The location of the source area for these gravels indicates that transport preceded uplift of the present continental divide (Oard and Klevberg, 1998).

I. **Demerdji Formation—Crimean Peninsula.** Gravels of the Demerdji Formation contain exotics transported up to 250 miles south from the Ukrainian Crystalline Massif (Lalomov, 2003).

Conclusions

The pioneers of modern geology chose to build their discipline around the fundamental paradigm of the time-stratigraphic analysis of the rock record. This entailed a philosophically rigorous view of uniformitarianism that is no longer viable. Given its obvious failures, another way of looking at the rock record is clearly needed, and the hydrodynamic approach offers many advantages—not the least of which is its comparatively robust empirical method. Diluvialists face a clear incompatibility between the time-stratigraphic method (and its derivative geologic column) and diluvial geology (Berthault, 2002; Froede, 2007; Reed, 2008a; 2008b; 2008c).

We suggest that the rock record, which appears so puzzling in terms of biblical history when forced into the framework of the geologic timescale, would be better understood if interpreted by means of a hydraulic evaluation of sedimentary composition and bedding. The ultimate goal of this revolutionary method would be the reconstruction of the Flood's hydrodynamic flow regime throughout its 371-day duration over the entire globe. This will demand numerical models currently beyond today's technology. A start in this direction has been made with the models presented by Barnette and Baumgardner (1994) and by Prabhu et al. (2008). However, we caution that any successful model must include the vital step of calibration to forensic sedimentologic data, and we further suggest that the task of collecting and cataloging such data become a primary focus of diluvial geologists. Even before these models are constructed, the qualitative and quantitative information provided by sedimentological data, especially those derived from rigorous provenance studies, should prove useful in determining paleocurrent vectors that can physically constrain the conceptual depositional flow regime of the Genesis Flood on a local to regional scale.

As such studies proceed, we should expect local to regional scale complexity in defining various flow regimes, given the multiple overlapping parameters; and we should beware confusion in the dimension of time, given the likely inapplicability of the geologic timescale (even in its relative chronostratigraphy) to the rock record. Yet the goal of understanding the flow regime of the Flood, perhaps even on a global scale, is certainly sufficient motivation to pursue these studies, at present, primarily through forensic field evidence.

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